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EXPERIMENTAL RESULTS ON ELASTIC BEHAVIORS OF COUPLING SYSTEM'S COMPONENTS

EXPERIMENTÁLNÍ VÝSLEDKY ELASTICKÉHO CHOVÁNÍ SPOJENÝCH KOMPONENT

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Abstract

The authors conceived and realized an original testing device destined to analyze the elastic elements from a special (patented) coupling system. This coupling system allows the changing of the deteriorated elastic elements without taking to pieces of the whole coupling system. The analyzed elastic elements are paralelipiped shape rubber, respectively Polyurethane part. These elements' elastic properties determine the whole coupling system's behaviors.

The original testing device main components are an electric strain gage transducer for force (load) evaluation, respectively a number of elastic steel lamellas, foreseen with electric strain gages, for displacement evaluation.

Using this original testing device, the authors established the elastic behaviors of the above mentioned elements parts.

Key words: coupling system, rubber, elastic elements

1. Introduction

The rubber components used in machine design are selected, between others, after their elasticity, fatigue strength, respectively their hysteretic behaviours. In the first few number cycles, the rubber specimens have a large hysteretic area, but after their internal, irreversible structural changing, will present a reduced hysteretic area. In the calculus are taken into consideration only these last properties. Due to the fact that up to 400 % strain their volume is practically constant, the Poisson ratio will be taken $\nu = 0.5$, and the elastic modules will be connected by relation $E = 3 \cdot G$.

In conclusion, in cases of the relatively small deformations, the rubber stiffness will depend on a single elastic constant (E) and the condition of the constant volume will be described by

$$\varepsilon_x + \varepsilon_y + \varepsilon_z = 0 . \tag{1}$$

When we intend to determine the value of E, first we'll establish the value corresponding to the static loading conditions E_{static}, and only after then the adequate dynamical one E_{dyn} .In case of deformations over 10% of the specimen's height, will be used *the large deformations' hypothesis.* In this case, for the compressed specimens will be used the relation

$$F = \frac{1}{3} \cdot E \cdot A \cdot \left(\frac{1}{\lambda^2} - \lambda \right), \tag{2}$$

where : $\lambda = \lambda_1 = 1 + \frac{\Delta \ell_1}{\ell_1}$ - *the rank of deformation*,

$\Delta \ell_1 \langle 0$ - the contraction of the specimen,

A - its cross-section's area,

$E \doteq E_{static}$ -the elastic module.

Taking into consideration the stiffening effect of the frontal steel plates, this relation became:

$$F = \beta \cdot \frac{1}{3} \cdot E \cdot A \cdot \left(\frac{1}{\lambda^2} - \lambda \right), \tag{3}$$

where β represents the so-called *stiffening coefficient*, which depend on the tested specimen's shape (fig. 1, where $a \rangle b$).

Due to the large deformation's hypothesis, the rubber specimens' stress state is usually different on the mono-axial one and consequently will be used a general theory. This theory will transfer (by calculus) the experimental data obtained by simply solicitations to the composed (compound) ones. In this case, the superposing principle of the efforts will not be valid and consequently, the general Hooke's law from metals cannot be applied. The developed Hooke's law for the rubber specimens [4] starts from the elastic strain-energy density u_i , and it is used not only for the stress-state evaluation, but also for the elastic behaviours estimation on large displacements. In case of the hypothesis of the isotropy of rubber materials, the elastic strain-energy density will not be influenced by the main strain directions' spatial layout, only by the ε_1, ε_2, ε_3 values.

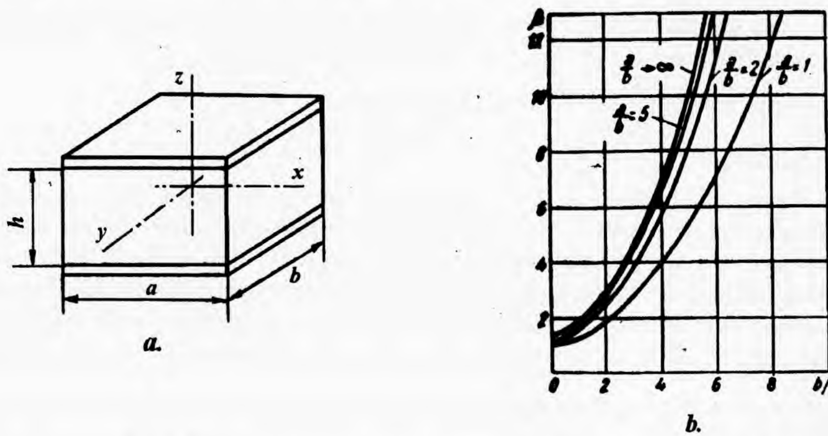

Fig.1 The specimen's sizes and the stiffening coefficient β

We can define *the rank of deformations* $\lambda_i, i = 1, 2, 3$:

$$\begin{cases} \lambda_1 = \sqrt{1 + 2 \cdot \varepsilon_1} = 1 + \frac{\Delta \ell_1}{\ell_1}; \\ \lambda_2 = \sqrt{1 + 2 \cdot \varepsilon_2} = 1 + \frac{\Delta \ell_2}{\ell_2}; \\ \lambda_3 = \sqrt{1 + 2 \cdot \varepsilon_3} = 1 + \frac{\Delta \ell_3}{\ell_3}. \end{cases} \tag{4}$$

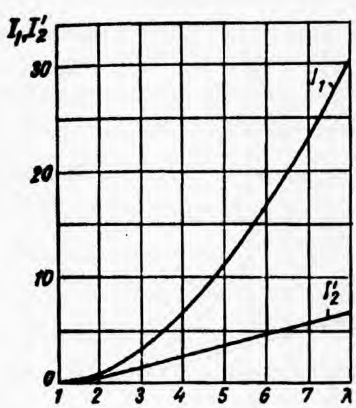

Fig. 2 The relationship between I_1, I_2' and $\lambda_1 = \lambda$

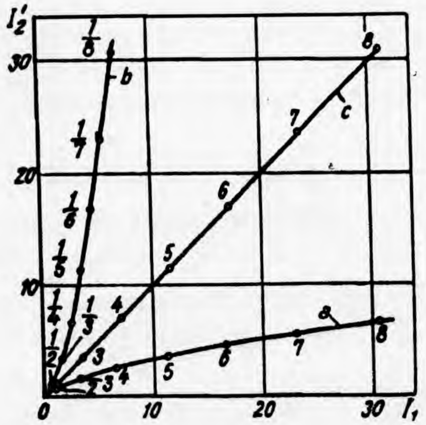

Fig. 3 The relationship between I_1 and I_2'

In the elastic strain-energy density calculus will be introduced *the invariants*:

$$\begin{cases} I_1 = \frac{1}{2}\cdot\left(\lambda_1^2+\lambda_2^2+\lambda_3^2-3\right)=\frac{1}{2}\cdot\left(\lambda^2+\frac{2}{\lambda}-3\right); \\ I_2' = \frac{1}{2}\cdot\left(\lambda_1^2\cdot\lambda_2^2+\lambda_2^2\cdot\lambda_3^2+\lambda_3^2\cdot\lambda_1^2-3\right)=\frac{1}{2}\cdot\left(\frac{1}{\lambda^2}+2\cdot\lambda-3\right), \end{cases} \tag{5}$$

which depend only on λ_i, and these ranks of deformations can be determined in a certain reference system.

Using some high-accuracy experiments, on can be establish the laws $u_i(I_1, I_2')$ for different solicitations and consequently became possible to predict the adequate stress-state for some imposed (known) deformations of the specimens.

Figure 2 shows the relationship between I_1, I_2' and $\lambda_1 = \lambda$, and figure 3: the relationship between I_1 and I_2'.

In this last figure the curve ***a*** is for tensile tests , ***b*** –is for compression tests, respectively ***c*** – for plane deformation state tests. The mentioned numbers represent values of λ.

In case of the mono-axial tensile test, between λ_i, we have the relations:

$$\lambda_2 = \lambda_3 = \frac{1}{\sqrt{\lambda}}; \quad \lambda_1\cdot\lambda_2\cdot\lambda_3 = 1. \tag{6}$$

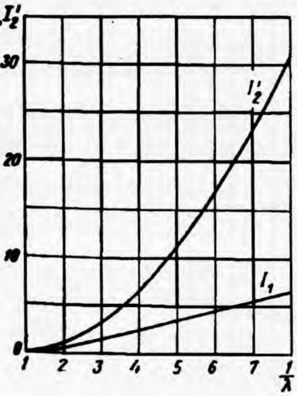

Fig. 4 The relationship between I_1, I_2' and $\frac{1}{\lambda}$ in case of compression tests

The last describes the condition of the constant volume deformation.

On can observe that only two from these ranks of deformations $\lambda_i, i = 1, 2, 3$ are independents and consequently the above-mentioned invariants can be expressed as function of λ_1, λ_2. The same relationship is preserved (valid) for compression with the $\lambda_1 = \lambda \in [0;1]$ condition (see fig.4). In [4] is described the methodology to obtain the elastic strain-energy density u_i. Taking into consideration that I_1 has a much greater influence as I_2', respectively that for relatively small deformations can be accepted a linear relationship

$$u_i = k_1 \cdot I_1 + k_2 \cdot I_2',$$

(where the constants k_1, k_2 describe the elastic behaviours of the material), with some simply tests became possible to obtain the requested relationship as a spatial surface.

For example, for tensile domain, on can use in this sense: mono-axial tensile test, bi-axial tensile test, respectively plane deformation test.

From them, we obtain the adequate characteristic curves $\sigma^* - \lambda$. σ^* represents the stress corresponding to the initial shapes and dimensions (sizes) of the tested specimens:

$$\sigma^* = k_1 \cdot \left(\lambda - \frac{1}{\lambda^2}\right) + k_2 \cdot \left(1 - \frac{1}{\lambda^3}\right). \tag{7}$$

Due to the fact that $\nu = 0.5$, for the relatively small deformations, starting from the well-known relationship $E = 2 \cdot (1 + \nu) \cdot G$, on can obtain:

$$3 \cdot (k_1 + k_2) = E \text{ , respectively} \tag{8}$$

$$(k_1 + k_2) = G \ . \tag{9}$$

2. The patented coupling system

Usually the coupling system's deterioration, especially the wear of its elastic elements, implies taking to pieces of the whole coupling system. This operation takes not only money, but a lot of amount from the precious working time. Such coupling systems' reparation represents a very great disadvantage for the whole working system (for example: in a plant or in the oil extractive industry).

It well known fact, that the coupling system's qualities are defined (strongly influenced) by its elastic elements' elastic properties. The main author of this paper conceived and realized a new, patented coupling system, destined especially for the oil extractive industry [1], [2], [3]. This new system's elastic elements are formed from some "Z"-shaped steel lamellas with rubber or Polyurethane part, forming together some compact parallelepiped elements.

Between *the main advantages* of this new coupling system on can be mentioned:

- It allows the elastic elements' changing without taking to pieces of the system;
- Assure a quick service and high manoeuvrability;
- These new elastic elements have high durability and silencer working of the whole system;
- The elastic elements present accented progressive elastic characteristic;
- Are eliminated the usage of the axial components;
- The radial components' sizes can be reduced with 30-90%;
- The bearings of the connected machines are protected from/against the shock;
- They can take over a 3^0 angular deviation, a $0.5\ mm$ circular deviation, respectively a $2\ mm$ axial deviation, too.

For some further optimization of this new coupling system, the authors conceived and realized a special testing device, destined to establish the elastic properties of these compact parallelepiped elements.

3. The stand description

The self-conceived stand is destined to test parallelepiped high-elasticity specimens (see fig. 1). Their testing will be, only under compression after z direction, using an universal testing machine. The main parts of the stand are: the octagonal electrical strain gages force transducer ***3***, fixed between the very high stiffness plates ***2*** and ***4***, which will measure the applied load ***F***; the tested specimen ***1***, located between the plates ***2*** and ***5***. To the plate **5** is connected the lamella $\boldsymbol{L_1}$, and to the plate ***2***, both the monitoring system ***6*** of the vertical constrain and the pairs of lamellas $\boldsymbol{L_2}$, $\boldsymbol{L_3}$ together with their supports ***7*** and ***8***. These last mentioned lamellas will put in evidence (will monitories) the lateral elongations of the specimen. The applied load ***F***, of the testing machine's jaws, will be transferred to the specimen by mean of the very high stiffness plates ***5*** and ***4***. The conceived system allows the positioning of all lamellas depending in the dimensions of the tested specimen. In the first step, the authors proposed the testing of some specimens having the following sizes: $a = 20.2\ mm$; $b = 15.5\ mm$; $h = 19.3\ mm$. The described stand is installed with a data acquisitioning system, and the ESAM strain indicator with 8 channels.

4. The calibration's results

As well as the octagon, as the lamellas were calibrated, following the process recommended by the international standards (number of tests, calculus of errors and so on). For this matter there were used force and displacement transducers class 0.1, produced by Hottinger-Baldwin Messtechnik. In figure 6 the calibration curve of the lamella L_1. We can observe both a good linearity and a reduced hysteresis for them. Also, the tests had in sight the signal stability and the temperature modification function (obviously, just in the permitted testing limit).

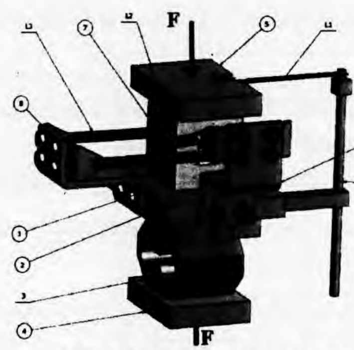

Fig.5 Schema of the stand

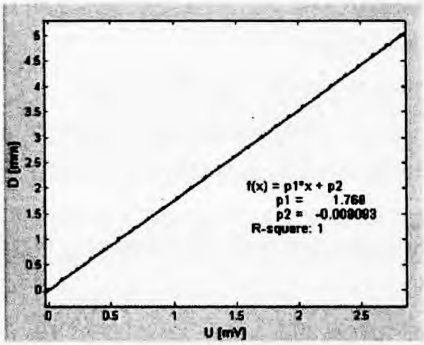

Fig. 6 Calibration curve for lamella L_1

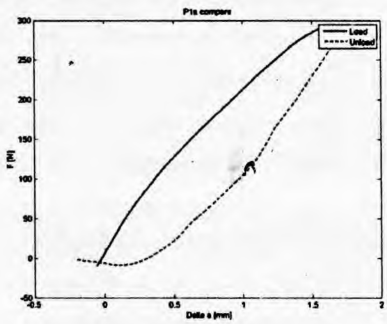

Fig. 7 Testing result

5. Testing results and conclusions

With this original stand were performed for several rubber and polyurethane specimens (with the same dimensions) such compression testes. In figure 7 is presented one of these comparative curves for loading and unloading of the specimens. Based on the above-described analytical relations, became possible to establish the rubber and polyurethane specimens for some further numerical calculuses of the mentioned patented coupling system.

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